MIXING APPARATUS AND METHOD

TECHNICAL FIELD OF THE INVENTION

This invention relates to the mixing of liquid and fluid materials.

BACKGROUND

Many conventional mixers have rotating shafts or moving blades that break the surface of the material being mixed and thereby entrain air into the mix. There are many cases where entrained air bubbles are very undesirable, for example coatings or lacquers that are to be spread very thinly, or casting mixes in which bubbles left in the solidified product would either weaken it or cause it to be scrapped. Conventional mixers also have to be cleaned between mixes, which takes time, risks cross-contamination and often creates a problem in disposing of the waste materials.

It is known to mix liquids using a reciprocating plate containing an array of relatively small apertures. These essentially work by forced division and recombination, and the amount of energy input required to reciprocate the

plate is high in relation to the amount and speed of mixing which is achieved.

It is also known to mix fluid materials by forcing the material through a relatively small and restricted aperture in a plate which thereby creates a high velocity jet. Again, such an arrangement is relatively inefficient, requiring a high energy input to achieve a given result.

The present invention seeks to provide a new and inventive mixing technique and apparatus which requires a relatively low energy input to achieve thorough mixing in a relatively short time.

SUMMARY OF THE INVENTION

The present invention proposes a method of mixing a volume of fluid material which includes creating an accelerating radial inward flow of fluid which converges to create an unrestricted axial flow within the volume of fluid.

Unlike prior art devices the axial flow is created solely by the convergence of fluid which has been accelerated radially towards a common collision region. Thus energy is only required to produce radial acceleration of the fluid, with no energy being expended in forcing the fluid through a restriction. It has further been found that the rapid change of direction which is produced in the collision region creates an extremely effective mixing action.

The invention further provides mixing apparatus which includes a container for holding a volume of fluid to be mixed, said container having an internal wall portion dividing the container into first and second chambers and which has an opening therein providing communication between the two chambers, the first chamber including a further wall portion which is spaced from the internal wall portion, and in which said wall portions are relatively movable to vary the volume of the first chamber whereby such relative movement causes an accelerating radial inward flow of fluid between said wall portions which converges to create an unrestricted axial flow through said opening.

The maximum dimension of the opening is preferably greater than 20% of the maximum dimension of the internal wall portion, preferably greater than 30 % and ideally greater than 40%, depending on the nature of the materials being mixed.

In some forms of the apparatus the internal wall portion may be provided by a separate wall which is movable within the container. Usually the movable wall will be a close sliding fit within the container, although there may be a clearance between the periphery of the wall and the container. In another form of the apparatus the internal wall may be fixed with the wall of the container and the further wall portion can be formed by a movable portion of the bounding wall of the container. The internal wall portion and the further wall portion may both be formed integral with the container if the portion of the container between the two wall portions is flexible, e.g. radially expandable or axially compressible.

BRIEF DESCRIPTION OF THE DRAWINGS

The following description and the accompanying drawings referred to therein are included by way of non-limiting example in order to illustrate how the invention may be put into practice. In the drawings:

Figure 1 is a vertical section through a first form of mixing apparatus in accordance with the invention;

Figure 2 is a plan view of the apparatus shown in Fig. 1;

~~Figures 3 and 4 are vertical sections through a modified form~~ of the apparatus;

Figures 5 and 6 are vertical sections through a further modification of the apparatus;

Figure 7 is a vertical section through a second form of the mixing apparatus intended for industrial use; and

Figure 8 is a vertical section through a third form of the mixing apparatus which is suitable for mixing small volumes.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring firstly to Fig.s 1 and 2, the mixing apparatus comprises a container 1 and a plunger 2, both of which may conveniently be moulded of plastics. The container 1 has a circular bottom wall 10, and an upstanding cylindrical side wall 11 surmounted by an inwardly-extending annular flange 12. The plunger 2 has a solid annular head 20 which surrounds a single circular opening 21 positioned in the central region of the head. In this embodiment the diameter of the opening 21 is about 45% of the diameter of the head 20. There is also a small annular gap 25 between the outer diameter of the head 20 and the side wall 11 of the container 1. A cylindrical shank 22 is upstanding from the head 20 to slide within the flange 12. The upper end of the shank 22 is bridged by a handle 23. Four circumferentially equally-spaced fins 24 project radially from the shank 22, joined to the head 20. The fins guide the plunger within the side wall of the container 1, passing through corresponding notches 13 in the flange 12. When the head 20 is located adjacent to the bottom wall of the container 1 the shank 22 can be rotated allowing the fins to pass beneath the flange 12 which thereby retain the plunger within the container.

Taking mixing wallpaper paste as a specific example, the apparatus is lined by a flexible plastics bag 3. It has been found that the type of bag described as having a star sealed bottom is particularly suitable. The bag is placed into the lower part of the container 1 beneath the plunger 2. The bag is fed through the central opening 21 to line the inside of the shank 22, with the mouth of the bag being secured to internal attachment formations 26 on opposite sides of the shank 22. However, the bag could be attached to the shank in many ways. A simple way is to fold it back over the top of the shank and put an elastic band around it. Another way would be to use a bag

with handles and use these to attach it.

The bag is filled with the required volume of water and a measured amount of paste granules are sprinkled onto the surface of the water. The handle is then gripped and the plunger is moved up and down ensuring that the stroke of the head 20 is below the surface of the water. Liquid in the portion of the bag below the plunger is thus caused to accelerate radially inwards as indicated by the arrows *A* towards a central collision region, at which point the converging liquid is forced to flow axially through the central region of the opening 21 as indicated by the arrows *B*. Depending upon the speed of movement of the plunger, the depth of liquid and the diameter of the opening, a jet of water may emerge centrally from the surface of the liquid, or an agitated body of liquid may arrive at the surface. There is a noticeable delay between the plunger starting to move downwards and the disturbance arriving at the surface. When the plunger is raised on its return stroke the liquid flows back through the opening. The primary flow back appears to be around the periphery of the liquid. Repeated lowering and raising of the plunger generates a thorough mixing action in which liquid is displaced radially producing a centralised vertical flow and is drawn down the outside into the region below the plunger giving a toroidal flow pattern. The agitation within the vertical flow and at the surface is dependent upon the proportions of the apparatus and on the speed, timing, and frequency of the plunger movement. Experiments have shown that if a colourant is placed near the outside region of a quantity of water in the bag three or four cycles will completely disperse it. When the wallpaper paste is sprinkled on the top of the water three or four strokes will mix it in efficiently. As the paste thickens the effectiveness of the radial pumping is reduced eventually leaving an

undisturbed central portion.

When mixing is complete the plunger 2 can be pushed down until the fins 24 engage under the flange 12 to lock the plunger leaving virtually all the paste accessible within the shank portion 22.

When the paste has been used the bag is thrown away and the mixer is left clean and ready for reuse.

It will be appreciated that the bag need not necessarily be used, although the apparatus must be washed thoroughly to remove the paste after use. The bag could also be used to line the container with the plunger placed within the bag, although obviously the plunger will require cleaning in such cases. This should be done immediately on completing the mixing, when the paste will wash off easily. Very thin and inexpensive bags can be used since it is fully supported within the apparatus.

The motion of the plunger could be more complex, e.g. incorporating rocking or circular motion into the basic reciprocating movement.

It will be appreciated that the container 1 could, in a simple form of the apparatus, be a conventional bucket provided with a loose-fitting plunger 2, optionally supplied with one or more bags. Such apparatus can be used very effectively for mixing thin pastes such as wallpaper paste.

It has been found that, in practice, the gap 25 between the plunger head and the container wall is important to allow the bag to roll between the

plunger and the container during the downward stroke of the plunger. This minimises drag on the plunger and reduces the risk of damage to the bag. This aspect of the apparatus is illustrated in more detail with reference to Fig.s 3 and 4 which show a modified form of the plunger with the head 20 in a raised and a lowered position respectively. In this case the head 20 is provided with an external annular downwardly-opening recess 27 and the outer periphery of the head 20 is arranged to slide against the inside of the wall 11 so that the gap formed by the recess 27 is of a defined width. The bag 3 is supported by the plunger and container against the hydrostatic pressure of liquid within the bag 3 apart from a small area where the bag spans the recess 27. The perimeter of the bag 3 should ideally be slightly larger than the internal perimeter of the container. When the plunger moves downwards the bag rolls smoothly into the recess 27 as shown in Fig. 4 so that the bag is still supported with minimum stress.

A further modification of the plunger 2 can be used to allow the bag to roll back on itself on both the upward and downward strokes, as shown in Fig.s 5 and 6. A second recess 28 on the upper margin of the head forms a second annular space between the plunger head and the container wall so that the bag rolls out of one recess and into the other during upward and downward movement of the plunger.

In these examples the movable internal wall is provided by an apertured plunger. It will however be appreciated that the apertured wall could be fixed within the container and the bottom wall of the container formed by a movable plunger. In such an arrangement the perimeter of the plunger can again be recessed to allow the bag to roll back on itself within the recess as

the plunger moves up and down.

Fig. 7 shows a form of the mixing apparatus which is suitable for industrial purposes. The apparatus can be used for mixing and transporting volatile solvents, biotechnology products, pharmaceuticals or water based paints for example. The apparatus comprises a container 1 and a plunger 2. The container 1 may be of metal, e.g. stainless steel, and the plunger 2 of plastics. The container 1 has a dished bottom wall 30 with a central opening 34, and an upstanding cylindrical side wall 31. A removable top 32 of shallow conical shape is joined to the side wall 31, e.g. by a clamp ring or by bolts through flanges with a suitable seal arrangement. A closure 33 is provided in the centre of the top 32, and the container is supported by legs 35 above a pallet base 36 to permit easy movement by fork lift truck.

The plunger 2 has a solid annular head 37 which surrounds a single circular opening 38 in its central region. The upper surface of the head 37 is of shallow conical form to assist fluid flow. The head is joined to an upstanding generally cylindrical side wall 39 which is formed with a shallow conical top wall 40 having a central opening 41. The side wall 39 contains three (or more) circumferentially spaced vertical indentations 42 which each receive a pneumatic cylinder 43 connected between the cylinder top 32 and the head 37. The plunger is thereby held with a constant annular clearance from the wall 31. The cylinders are operated to produce vertical reciprocation of the plunger, when required, by control valves and pneumatic logic 44 mounted in the top 32, which is supplied from an external air supply via a releasable connection 45.

A bag 3 is initially supplied in an evacuated condition for ease of insertion through the top of the apparatus by removing the closure 33. The bottom end of the bag is provided with a collar 48 and valve 49 which is sealably fastened into the bottom opening 34 by a clamp ring or the like. The top of the bag may be held in position by a drop-in support spider 60. The bag 3 will usually be filled from the bottom via the valve 49 with the plunger in the raised position as shown. The bag is only filled to a volume which provides sufficient capacity to roll between the head of the plunger and the wall of the container when the plunger is lowered, as described above in relation to Fig.s 3 and 4. The mixing action is substantially as described above. If desired, the container 1 may be jacketed and provided with a heater to warm the contents during the mixing process.

For shipment of the contents the valve 49 is closed and an external cap can be applied as a second seal. The top closure 33 is secured in position to ensure that the container is completely sealed. When the shipment arrives at the user the closure 33 is removed and, after connection of the air supply and re-mixing of the contents, the mixed materials can be drawn off through the valve 49.

When empty, the bag 3 can be removed and disposed of, probably by recycling.

The bag could be adapted to be opened at the top, to permit the addition of solids for example, and then re-sealed for transport. The container 1 could be rectangular, and may be collapsable to save space on the return trip.

In the form of the apparatus shown in Fig. 8 the plunger is formed integrally with the container. The apparatus is particularly suitable for kitchen use. A moulding 50 of flexible plastics such as polythene includes a cylindrical portion 58, the upper end of which may be provided with a removable closure 52. At the lower end of the cylindrical portion 51 the wall of the container extends inwardly to form an annular ring 53, below which the wall is formed into a series of corrugations 54 forming a bellows-like bottom portion 55 closed by a bottom wall 56.

In use, the container is filled with materials to be mixed up to a level *L* above the ring 53. Pressing down on the top of the container causes the bellows portion 55 to collapse producing a similar radial mixing action as the contents are squeezed between the ring 53 and the bottom of the container, mixing the contents. When the container is released the bellows will expand again. If the container has a screw top or similar sealing closure it can be packed with the bellows squeezed up so that when the container is opened the bellows expand drawing air in. Packed in this state the container is particularly rigid, and any leakage in storage would cause premature expansion making the fault obvious. Such a container would be useful for mixtures that tend to separate in storage allowing the user to easily remix the contents. They could also be sold prepacked with one component of a mix so that when they are opened and the second component added they can be easily mixed together. Both components could be packaged separately one on top of the other ready for mixing, for example milk shakes. The action of opening the container could also be used to release one component into the other, for example the powder added to milk to produce rapid setting puddings. Another possibility is to supply one component (e.g.

paint colourant) in the bellows portion 55 with a peel-off seal across the top of the ring 53. The second component (e.g. a paint base) could be sealed in a bag, which can for example be supplied in the top section.

In each of the forms of apparatus described above it will be appreciated that because the mixing action is generated below the surface of the liquid and can be controlled to limit the disturbance of the surface of the liquid, it is possible to mix with very little air entrainment. When using a bag with the apparatus no part of the plunger breaks the surface of the liquid. All forms of the apparatus can thus form the basis of an excellent vacuum mixer. There is little or no entraining action and liquid is being constantly brought from the bottom of the vessel to the surface where it will be exposed to a vacuum which helps to remove any air bubbles. With a heating jacket as well as a vacuum the apparatus can form a very effective dissolver for air free solutions.

Although in most cases the container and plunger will be of circular section they could be of any cross-sectional shape, e.g. square or rectangular, ideally with rounded corners.

It will be appreciated that the features disclosed herein may be present in any feasible combination. Whilst the above description lays emphasis on those areas which, in combination, are believed to be new, protection is claimed for any inventive combination of the features disclosed herein.